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ALIMENTARY BEHAVIOR AND ORGANIC ADAPTATION TO DESERT ZONES

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ABSTRACT. A brief description of the climate of the Sahara is followed by a detailed description of the diet of the nomadic Meharists. Religion and custom as well as practical expediency are discussed as reasons for the selection of such imbalanced eating habits. A detailed analysis of the nutritional value and substantial deficiencies offered by the diet are shown to be basic to this native group's adaptation ability to the torrid desert climate. Other authors' tests on both man and animals are discussed and compared in terms of validity and accuracy.

The permanent aggression which constitutes torrid desert climate causes a unique organic regulation which puts into play highly organized and differentiated physical, chemical and metabolic processes which serve homeostasis. /33*

This regulation, well studied in animals which lend themselves easily to experimentation but less well studied in man, seems to us to be a reality which is difficult to put aside if we wish to understand the alimentary behavior of aboriginal Saharan populations.

In fact, it seemed of interest to us to observe in detail the life of these populations and their reactional attitude under the influence of a highly aggressive climate. It was not within our capability to undertake an exhaustive study of the alimentary behavior in the Sahara zone. Our remarks will be of value only as observations which are frequently deprived of experimental basis, which alone is valid. In addition, as a typical example, we attempted to examine how this study might be worked into currently accepted data, how it might affect these data and, paradoxically, often deviate from them.

This typical example was selected from among an actual Saharan population which was nomadic (inasmuch as a sedentary way of life frequently creates an artificial microclimate which invalidates raw data), and easy to observe and keep under medical surveillance.

To this end, we selected the Mehar group of Saharans, who fulfilled these conditions.

Of course, these remarks reply only to alimentation indigenous to the Saharans, a fixed and unchangeable local alimentation.

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* Numbers in the margin indicate pagination in the foreign text.

Overall Climatic Data

The Tidikelt, the region in the Sahara where this study took place, is a zone which has a dry continental desert climate.

"The temperature is higher than the French Sahara and one of the highest in the world. The summer mean fluctuates around 43°, and reaches 49°. The /34 mean for the winter months is 14°. The range between the extremes, which reaches 52.6°, indicates that we are dealing with a characteristic continental climate." (Cornand, Maire and Savelli). The very slight hygrometric reading in the air makes it possible to stand such temperatures as 51° only inside tents, which we were able to prove personally.

1. General Characteristics of Saharan Alimentation

The nomadic members of this mounted group take on supplies once a month, and not very long ago only every other month, at a meeting point. The supplies taken on are in a precise quantity determined for each product, the "aouine" from which the meharist will live throughout the month.

Breakdown of monthly "aouine":

- couscous: 2.4 kg,
- paste products: 2.4 kg,
- flour: 15 kg,
- sugar: 4.75 kg,
- oil: 2.5 liters,
- salt: 0.6 kg,
- preserved sardines: 12 120-gram cans,
- tomato paste: 20 100-gram cans,
- onions: 1.500 kg, and
- tea: 750 grams.

A first glance at this table indicates that the meharist's daily diet is basically monomorphic and sparsely austere: there is no mention of bread, meat or fresh fruits and vegetables. The alimentary rhythm is two main meals, at noon and in the evening, the meals consisting of a single plate:

- "chorba" in the morning (very thick paste soup with spiced tomato sauce), and

- "couscous" in the evening without meat or vegetables. In addition, on the average of every three hours the Saharan drinks very concentrated and sweetened tea.

In brief, Saharan alimentation is nothing more than cereals consumed with a great deal of oil and sweetened tea.

The rigour of this diet has not been imposed like an intangible dogma. The Saharan, like many individuals submitted to a diet lacking in animal protein, is very fond of meat: a gazelle killed or a goat purchased sometimes help toward enriching the diet, but the episodic and very contingent value of these products may not be considered an integral part of the diet.

This alimentation, whose deficiencies are quite obvious, seems to us to be unadapted to the conditions of life in the Sahara. In fact, with a temperature of 51° within the tent it would seem absurd to eat a steaming soup dripping in oil and garnished to taste with pepper and pimento. And yet this attitude astonishes only us ourselves because for the Saharan, in contrast, it seems well chosen: the grease, the oil and the hot chorba are indispensable for resisting the heat. This is the kind of answer given by a meharist when questioned about it. Another nomad told us: "You have to eat a lot of pimento if you want to withstand the summer heat, the fire inside you will help you overcome the fire outside." /35

Was this just a euphemism or should we, on the contrary, look into it as a rational explanation which empiricism has imposed upon the nomads?

We will summarize, briefly at first, the factors which govern this alimentary behavior.

1. Economic Factors

The Sahara, a very poor country agriculturally, cannot survive on its own resources and imposes frugality in its inhabitants. In its composition, even the meharist diet is not a "deluxe diet." Composed of dry imported products (pastes, wheat and semolina), it eliminates any products which are rare and might spoil in that region: fresh fruits and vegetables, meat and milk products.

2. Climatic Factors

Contrary to what we may think, their falling upon the choice of their food is deficient to indigenous meharists. The frightening heat of the summer months slows down the cycle-motor behavior considerably, but it to no degree changes the composition of the meals, which remain the same winter and summer. This fact again strengthens the notion according to which the organism of the Saharans offers adaptation faculties and the proper metabolism, thereby assuring its thermoregulation, due to energy contributions, which are totally different from those necessary for the transplanted European. The effect of climate plays an indirect role on the choice of food products. In fact, the heat makes any preservation of fresh foods impossible. Meat must be eaten immediately, fresh vegetables dehydrate rapidly, and open cans of preserves spoil rapidly. Because of this fact, the meharist restricts his choice to flour, semolina, pastes and pre-dried unspoilable products.

3. Religious Factors and Custom

These are of prime importance because they severely condemn a substantial number of foodstuffs which could compensate for the lack of meat and fresh vegetables. This factor is at the source of the irrevocable repulsion the meharist has for any preserved food whose origin is not known to him. Without even considering pork, of course, which is painted by a redhibitory defect, /36
all other preserved meats -- beef, fowl or fish -- are not eaten by the Moslems because these meats come from animals which have not been blessed by ritual slaughter. Even when a gazelle which has been killed during hunting is added

to the menu, it is not eaten by the meharists unless it has been only wounded by gunshot and then sacrificed according to the rites of the Koran.

We were astonished by the meharist's refusal to eat rice. Is it not a rich food which cannot spoil and which is easily handled, qualities required for it to be considered by the Saharan? Of course... but rich is the food of the "Haratins" from the Soudan, the decendants of slaves. How could it be worthy of the meharist's table? This case among many others sheds some light on the effects of custom and prejudice on eating habits.

4. Practical Factors

These are not negligible. The mounted group is an extremely mobile, light unit which "has no camp followers" and which cannot live off the land. The camel must not be overloaded, in order to preserve his strength and ability to perform. Therefore, food rations must be light and highly condensed. Preserved products answer this need well, but the metal containers are incompatible with the required norms. It is for this reason as well that the meharist does not load himself down with dried or smoked meats, or dry fruits and vegetables other than some onions.

A quantitative and qualitative study of this diet will bring some ideas up to date and clarify the advantages and drawbacks of these very restrictive eating habits.

Qualitative and Quantitative Study

This study will bring to light the drawbacks of these eating habits. Table 1, in which the products constituting the monthly "aouine" are enumerated, specifies the quantities, the total caloric value and richness in water, proteins, lipids, glucides, mineral salts and the main vitamins. In addition, it gives the daily yield of each nutriment and the theoretical daily requirement. We will point out that the diet is composed basically of cereals: semolina, flour and food pastes. According to this table, the meharist's monthly aouine consists of 113,405 calories, that is 3780 calories per day. This represents a substantial energy yield, corresponding to the needs of an active worker, not someone who is sedentary during the cold season.

Is this value adapted to the meharist's conditions?

Kark and Johnson Equation

These authors attack the nutritional problem of armies in the field and found a linear relationship between the number of calories per day which were indispensable for the combatant's organic equilibrium and the mean ambiant temperature. This relationship is written: /37

$$\boxed{\text{Calories/man/day} = 4151 - 28.62\ T}$$

in which T represents the mean ambiant temperature.

Table I

Food	Quantity monthly (kg)	Input caloric daily	Water (grams)	Protein (grams)	Lipids (grams)	GLUCIDES in grams	Na in grams	K in grams	Ca in grams	P in grams	Ratio Ca/P	Iron (grams)	Vitamins (in milligrams) A	D	PP	BI	B2	C	Others
Pastes	2.4	240	288	720	36	1 682	0	3,120	0,538	3,456	0,15	26	0	0	48	2,4	1,44	0	
Flour	15	1 735	0	1 425	210	11 100	0	0	3,750	24	0,15	345	0	0	0	37	0	0	Folic acid
Sugar	4.75	625 5	47	0	0	4 750	0	0	0	0	0	0	0	0	0	0	0	0	
Oil	2,5	750	0	0	2 500	0	0,003	0.03	0	0	0	0	0	0	0	0	0	0	
Sardines	1.450	108.7	797	362	195	0	10.8	3.8	0,435	4.5	0,1	22	0,36	0	262	0,72	1.45	0	
Tomato concen-trate	2	15 3	1 880	20	6	80	0.36	2.6	0,2	0.5	0,4	10	6	0	14	1	0,6	320	
Couscous	2.4	280	0	264	216	1 848	0	0	1,2	8,4	0,14	0	0	0	0	35	0	0	Folic acid (vit.E)
Salt	0,600	0	0	0	0	0	480	0	0	0	0	0	0	0	0	0	0	0	
Tea	0 750	0	0	0	0	0	0 003	0 127	0,002	0,007	0,3	0	0	0	0	0	0	0	
Onions	1 500	24	1 305	540	3,5	150	0,01	1.95	0.52	0 52	1	9	0.045	0	1,5	1,5	0,45	225	
Monthly total			4 322	3 331	3 166,5	19 610	491	11.6	6,6	41,4		412	6,36	0	125,5	77,6	4	545	
Daily intake		3 780	144	111	105	653	16	3,8	0,2	1,4	0,11	13.4	0,21		4	2,5	0,13	18	
Daily caloric value				372	648	2 594			u										
Daily require-ment				45 to 60	50 to 100	250	4 to 6	2 to 4	0,8	1	0,8	10 to 20	0,3 to 0,6	0,004	15 to 25	1,5 to 2,3	2,2 to 3,3	70 to 100	

Tr. Note: Commas indicate decimal points.

Let us apply this ratio to the Saharan:

- in winter: the mean temperature is 14°. We will therefore have: $4151 - (28.62 \times 14) = 3750.60$ cal/man/day;

- in summer: the mean temperature is 44°. We will therefore have: $4151 - (28.62 \times 44) = 2893.72$ cal/man/day.

We see that the caloric input for this Saharan ratio averages 3800 calories per day and is identidical to Kark and Johnson's data for the winter intake but above those data relative to summer intake.

Following the work of these authors, the F.A.O. stated that the caloric requirements of any given subject should be increased or decreased by 3% when the mean temperature varied 10° with respect to the mean temperature in the country being considered, a temperature fixed at 10°.

A. Proteins

The idea of a nitrogen balance is quite old, having appeared in the works of Magendie in 1816 then Boussingault (1839) in seeking the first precise information on the organic nitrogen requirement. The "protein minimum" has been defined by Lusk as the minimum quantity of proteins needed to maintain the nitrogen equilibrium and normal health. According to the authors, this quantity varies from 44 grams per day (Sherman) to 118 grams (Volt, Atwater and Benedict). These values vary over a broad spectrum and these divergences show the difficulty which exists in defining a standard protein requirement, a variable concept which depends on many factors: internal metabolic factors and external factors which vary with the climate, and the energy spent. The mean values proposed by Chittenden and Hinhede of 1 gram of protein per kilogram of body weight seem to be a mean confirmed by the works of Lucie Randoin.

However, we should be careful to note that "there is not one single protein minimum requirement, but rather as many requirements as there are albumin material, the value for replacing these nitrogenous foods varying considerably from one nitrogenous food to another" (Tremolieres). The minimum protein requirement varies with respect to the food regimen, as has been shown by Rubner. In fact, different foods are not equal with respect to the law of required energy intake. The eating habits of the Saharan offer us a typical example of this.

In fact, the distinction between animal proteins and vegetable proteins is a well-known idea. Animal proteins have an amino acid content which is very close to human structural proteins, whence we obtain a greater coefficient of use. These are the so-called "biologically high-value" proteins. /40

By studying the nitrogen balance, Thomas determined the percentage of protein used from various foods. Table II summarizes his findings.

The cereals and flour which form the basic ingredient in the Saharan diet have a utilization coefficient which is very low and these foods are therefore of very low biological value.

TABLE II
(According to K. Thomas's Summary)

Origin of Proteins	Percentage Used
Beef.	104.7%
Milk.	99.7%
Fish.	94.5%
Potatoes	78.9%
Flour	39.6%

In addition, there is the effect of the digestive utilization coefficient of the foods which equals the ratio:

$$\frac{\text{Quantity of food assimulated}}{\text{Quantity of food absorbed}}$$

This coefficient has been calculated by Atwater for various foods.

TABLE III
(Summarized according to Atwater)

Food	Digestive Utilization Coefficient		
	Proteins	Glucides	Lipids
Meats, eggs, milk products	0.97	0.98	0.95
Cereals, pastes	0.85	0.98	0.90
Dry vegetables	0.78	0.97	0.90

Let us apply these data to the diet of the Saharan. According to Table I, he consumes 111 grams of protein per day, a quantity which is of course more than sufficient since he requires only 70 grams of protein per day on the average. However, we must not forget to take into count the restrictive /41 factors, Atwater's utilization coefficient and Thomas's biological value.

Cereals have a utilization coefficient of 0.85 for proteins.

The Saharan therefore uses only: 111 × 0.85 = 93.35 g of proteins.

In addition, the cereals have a 40% metabolic usage. These are proteins with a low biological value.

In his "metabolic reserve" the Saharan therefore has only:

$$\frac{93.35 \times 40}{100} = 39 \text{ grams of protein.}$$

This last value, which alone is usable, is clearly insufficient and results in a permanent proteic hunger in the Saharan.

Osborne, Mendel and Rose's already old works showed the existence of complete proteins which guarantee an increase and buildup in normal cells and for incomplete proteins in terms of energy and the physique. The eight indispensable amino acids (tryptophan, lysine, valine, leucine, isoleucine, methionine, threonine and phenylalanine) must be part of the diet in a definite ratio: we require first ten milligrams of isoleucine, 6.5 mg of tryptophan per kilogram of body weight for adult males. This is true, as is emphasized by Gounelle, because "these quantities are demanded for the repair of worn tissue, the requirement for growth and the production of antibodies and hormones... It is also vital to take into consideration the combination and respective balances of amino acids. Thus, cystine and tyrosine, indispensable amino acids, through their presence in sufficient quantity permit economy in terms of two indispensable elements: methionine and phenylalanine."

Let us look at the Saharan's diet!

The meharist consumes 15 kilograms of flour per month, i.e. 0.5 kg per day on the average. By referring to the tables for the food content we see that 500 grams of flour yield 830 milligrams of tryptophan, i.e. for an average weight of 61 kilograms, 13 milligrams per kilogram of body weight. This is quite sufficient, but far from being entirely simulated by the organism. We must also take into account two restrictive utilization coefficients in digestion and the percentage of use. Which, for flour, gives us 4.5 mg of tryptophan which the organism can use. The same reasoning for isoleucine gives us 15 milligrams which are actually used for this amino acid. These values are normal and sufficient for the eating habits of the Saharan.

The Protein Index

We will define this idea which, along with the percentage of use, specifies the nutritive value of a protein and we will see that calculating the /42
protein index will show us another lack in the Saharan diet.

Every protein is characterized by a combination of amino acids in varying proportions. Certain indispensable amino acids exist within the protein in an amount which is below the normal amount required to guarantee a good energy balance. "This relative lack of protein in one indispensable amino acid or another constitutes the limiting factor in its biological value." (Gounelle). Theoretical calculation of the optimum value which each indispensable amino acid should reach within the protein has permitted us to establish a theoretical combination expressed in milligrams of amino acid per gram of aminated nitrogen. The protein index will be represented by the ratio in percentage between an aminated acid limiting a given protein and the amount of this same amino acid in the representative combination. Thus, let us assume we have a protein containing 50 milligrams of lysine, the limiting amino acid, per nitrogen gram of this same protein. The theoretical combination yields a value of 100 milligrams of lycine for the protein in question. The protein index will be the percentage ratio between these two values of lycine, i.e. 50%. In addition, this value of 50%, still with respect to theoretical calculation resulting from dietary balances, is the minimum value which a protein index must attain to confer a sufficient nutritive value to any given nutriment. For cereals forming the basis of the Saharan's diet, this index varies from 30% to 45% without ever exceeding this value.

Thus, these figures show the lacks in the Saharan's diet, which is at first glance rich in calories and proteins. From this fact we see that the global caloric value is a false criterion to indicate the energy value of foods. "Let us consider separately and in terms of efficiency the alimentary proteins classed clearly into two groups: the biological value of the proteins of animal origin is as a general rule clearly superior to that of proteins having a vegetable origin. The total proteins in eggs are most efficient, while those of corn count among the more mediocre. The concept of quality in proteins therefore indicates a concept of quantity. Satisfying the nitrogen requirement will require more proteins because they are less efficient." (Jacquot).

Protein requirement may be calculated according to the simple formula:

$$Y = Q \times \frac{V.B.}{100} \times \frac{C.U.D.}{100}$$

In which:

Y represents the protein requirement,
Q is the food's protein content,
V.B. is the biological value (Thomas), and
C.U.D. is the digestive utilization coefficient (Atwater).

As applied to a Saharan, knowing that: /43

Q = 111,
V.B. = 40%,
C.U.D. = 78%.

we will have

$$Y = 111 \times \frac{40}{100} \times \frac{78}{100} = 37.7.$$

This indicates that the protein requirement in the Saharan's diet is satisfied only in a proportion close to 36%.

B. Lipids

Lipids are calorigenic elements par excellence, containing 9.3 calories per gram combusted, while proteins and lipids offer 4.1 calories per gram each.

The daily required quantity values with respect to the energy needs and climatic conditions. An intake of 70 grams per day seems to be a normal and sufficient quantity. This value is increased in cold countries, where heavy laborers such as Belgian miners or Canadian lumberjacks consume up to 200 grams of lipids per day. The cold causes preferential use of fats, as has been shown by Kayser in his study of the daily respiration of guinea pigs subjected to cold. In addition, the works by Cahn and Houget have shown an enrichment in phospho-lipids in the liver during rewarming, a reaction indicating a non-use of lipids and a reserve deposit affected by heat.

In warm desert climates, the fat intake should be substantially decreased or eliminated, calorigenic food being superfluous, inasmuch as the subjects lives in an ambiant temperature substantially surpassing the thermal balance. And so, what does the meharist's aouine offer him? An average of 105 grams of fat per day, taken in with the olive oil in which he literally soaks his foods. In addition, this is a vegetable oil which, with the exception of vitamin E, is quite poor or lacking in indispensable lipo-soluble vitamins.

Substantial intake of fats is accounted for rather by atavistic reasons than organic needs, and this would explain the disproportionate intake of lipids in a climate demanding almost no thermogenesis.

C. Glucides

The alimentary intake of glucides should be very substantial because these nutriments furnish 50% of the energy exhausted. For a normal organism, 250 to 500 grams of glucides are required per day.

Table I shows that the Saharan's daily average intake is up to 650 grams, a substantial amount which largely suffices organic needs. These glucides come primarily from the starch in the flour, from the semolina and the sugar /44
consumed with the tea. The richness in the glucide intake in the Saharan's diet permits palliation of the imbalance in the protein and lipid intakes. This is due to the carbohydrates, energy substances which are poorly calorigenic, that the meharist achieves this metabolic compensation which permits him to achieve his strength and maintain normal weight.

Before beginning the study of energy processes inherent to such eating habits, we will glance at the values of the plastic and catalytic intakes and note their weakness and inadaptation.

D. Water and Mineral Salts

Study of the regulation of the hydro-electrolytic principle affected by the heat is too vast a problem for the limits of this study. The works of Lemaire and Pille, and Metz and Lambert are authoritative in this field. We will undertake this study only from a restricted viewpoint, restricting ourselves to intense sodium chloride spoliation and its organic consequences.

During the summer, the quantity normally ingested by our Saharans varies from 8 to 15 liters per day per man. This water serves to counterbalance the sudation losses exacerbated by the heat and intense thermolysis. The sudation losses may easily reach 10 to 12 liters per day. Knowing that sweat contains two to four grams of NaCl per liter, it is easy to get an idea of the intense sodium chloride spoliation undergone by an organism exposed to this climate. One should not be unduly alarmed over the importance of these losses, which are lessened by the regulatory mechanisms which permit the organism to adapt its requirements and wastes with respect to a homeostasic level.

It is thus that we have shown that organisms accustomed to living in a tropical climate eliminate a urine with a low saline concentration, the indispensable sodium chloride being retained by the organism. In addition, urinary elimination is practically zero during the torrid season. What urine there is is quite rare and highly concentrated in dissolved substances with the exception of NaCl. This oliguresis is part of the regulation of the water motion by Verney's osmo-hormonal reflex arc.

An animal adapted to a desert climate, the Dipodomys or kangaroo rat, shows us the point to which the adaptive mechanisms may be pushed. In fact, this mammal eliminates a urine which is almost in a crystallized state, it is so hyperconcentrated and lacking in water. Precise experimental studies have partly indicated the dehydration mechanisms in a desert milieu.

The Lemaire and Pille Experiment

These authors studied dehydration by water depravation in mammals who sweat cutaneously (horses) which were submitted to physical strain in a tropical environment. They note that "dehydration through water suppression and sudation constitutes an intermediate state between dehydration through lack of /45 salt and dehydration through water privation." This is mixed dehydration during which the water deficiency affects the extracellular section as well as intracellular section. The interstitial liquids are most affected by dehydration, while the plasma is relatively protected.

This dehydration is accompanied by hyperconcentration of the Na + Cl cations and proteins in the plasma.

The Elkinton and Taffel Experiment

The experiment involved dehydration through water depravation in a dog over a period of 20 days. Aside from rapidly appearing signs of suffering, the authors noted an oliguresis which appeared only on the third day, with a drop in the urinary excretion of sodium and an increase in that of potassium. This was a question of dehydration affecting two liquid compartments: the extracellular area especially, and, to a lesser degree, the intracellular area.

The Mac Cance Experiment

Dehydration through water depravation of voluntary subjects placed in an overheated atmosphere for four days.

This test, which comes closest to the dehydration encounted in desert zones, shows also a water deficit with a substantial electrolytic loss.

All these tests have demonstrated and emphasized the imperative need of a water and sodium chloride intake which would counteract the losses caused by intense thermolysis. All the more since the sudoral concentration of NaCl increases with the length of exposure to heat (Adolph, Pitts and Ladell). The compensatory ingestion of water, regulated by the first mechanism, is a palliative phenomenon whose corrective effects can be exercised only within certain limits. In fact, Lambert has shown that for sudation of 250 grams per hour, 95% of the losses are replaced by water ingestion.

For sudation of 500 to 700 grams/hour, only 55% of the hydrochloride lost is replaced by ingestion of water and salt.

"Therefore, for heavy and prolonged sudation, a practically ineluctable water deficiency is produced. This progressive and constant debt constitutes Adolph's "voluntary dehydration" (Vergnes). Intense and prolonged dehydrations also cause disturbances of the membrane's permeability, with difficulties in absorption and the appearance of a water lack.

Effects of Progressive Adaptation

Adaptative processes, which tend to preserve homeostasis, go into play in the subject submitted to a torrid desert climate. The first phase, the so-called accommodation phase (Giaja) is characterized by hypovolemia, hyper-concentration, and the sudoral escape of sodium chloride. Then these phenomena are damped during the adaptation phase on the condition that the subject not have been submitted to severe aggression exceeding the organism's corrective /46
capabilities. This adaptation in particular shows oliguresis with urine which is concentrated but low in NaCl, and a gradual diminution of chloride losses by sweat (Metz and Lambert)(Figure 1).

One special problem may be considered to concern the consumption of sodium bicarbonate mineral waters in a desert climate.

The consumption of these waters has been proposed in order to palliate the loss of sodium chloride. Certain reserves have been expressed by some authors who consider the use of alkaline water to cause deposits of phosphatic renal lithiasis. This is a reservation which Mathieu de Fossey does not go along with: "The urine excreted tends to be more acid than normal and consequently the use of alkaline water can only be favorable and cause true renal rest."

Two important aspects of this question should be pointed out:

On one hand, the quasi-total inhibition of diuresis and, on the other hand, the wave of alkalosis which heavy sudation may cause.

The inhibition of diuresis deprives the organism of a vital regulatory /47
mechanism for the acid-basic balance. The hydro-saline losses are exercised sudorally and, to a negligible extent, renally. In this case, bicarbonated water and sodium chloride water will be useful because of its saline ion addition.

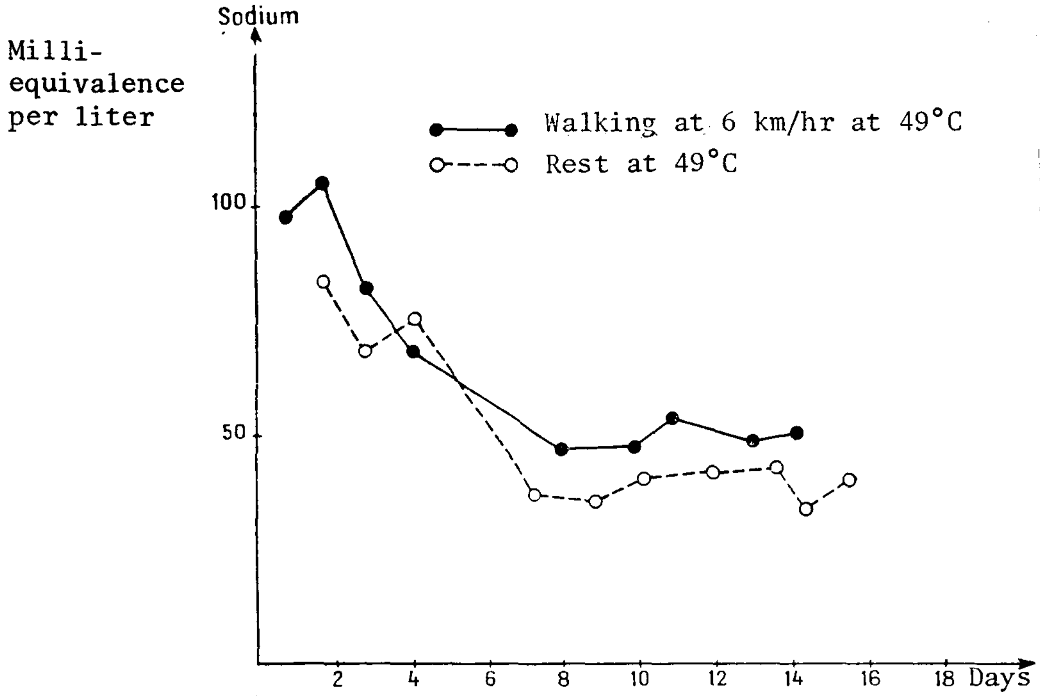

Figure 1. Sodium Concentration in the Sweat (in milliequivalence per liter).
Sodium and chlorine losses decrease during the first week of acclimation, and are restored later (according to Metz and Lambert, at Vergnes).

It should also be noted that sudation due to heat is more acid than that caused by work. The pH varies from 5.2 for heat to 6.6 for work. If it is substantial, this sudation can cause spoliation of acid valences with a wave of metabolic alkalosis. It is conceivable in this case that bicarbonared water would only aggravate the alkalosis and its use would prove to be counter-indicated.

It would be interesting to study the significance of these two phenomena working against each other to achieve a clear idea of the indications of a mineral intake in a desert climate.

Potassium

The intake of potassium is assured primarily by the pastes, sardines, tomato concentrates and onions. The normal daily needs of three to four grams are not covered because the Saharan diet yields only 0.386 grams per day.

This cation is of additional interest and from a purely speculative viewpoint we might imagine the application of E. Bachrach's concept of thermal-cation equilibrium to the human body. In fact, this author, in studying the compensation of the effects of potassium by those of the temperature, noticed that the optimum temperature for a biological unit, the comfort-zone, is found to be displaced toward higher temperatures in a potassium-enriched environment.

Bachrach made the observations on colonies of lactic bacteria whose biological activity, fermentation power and optimum temperature increased parallel to the concentration of K^+ ions. Such as the concept called by this author thermal-cation balance, a concept confirmed by Losina Losinskiy on paramecia with a resistance to heat evolving parallel with an enrichment of the environment in K^+ ions, by Lundberg on mammal nerve fibers, by Bouckaert and Guillot on the isolated heart of snails, and by Reinberg on the spontaneous activity of invertebrate and mammal hearts. "Finally Bachrach's results and those of Merker indicate an increase in the resistance to heat in whole animals when they receive potassium" (Reinberg).

Might we not imagine the same effect on the entire human organism and assume that regular consumption of potassium might permit the buildup of better resistance and adaptation of our functions to the aggressive action of heat?

Calcium

Daily required amount: 0.8 g/day.
Amount received through diet: 0.18 g/day.

Phosphorus /48

Daily required amount: 1 gram/day.
Amount received through diet: 1.38 g/day.
Ca/P ratio equal to 0.11 in the Saharan's diet instead of the normal value of 0.8.

Iron

Daily required amount: 10 to 20 milligrams/day.
Amount received through diet: 13.4 mg.

E. Vitamins

1. Vitamin A

The meharist's sources of Vitamin A are rather precarious inasmuch as they come only from the consumption of onions and tomatoes. In addition the almost non-existent consumption of fresh vegetables deprives the organism of the endogenous intake of Vitamin A from the provitamins of vegetables, the carotenes, α, β and γ in particular.

The required intake is 0.3 to 0.6 mg/day. The Saharan's intake of 0.21 mg is based on his regular consumption of sardines, tomatoes and onions.

Incidences of hypovitaminosis A in the Saharan's organism becomes obvious not so much by cutaneous alterations as by problems with night vision and a decrease in the organ's resistance to infections.

2. The Rachitis Preventive -- Vitamin D

The Saharans have no source of Vitamin D. The only intake of an endogenous origin would be in the transformations within the provitamine cells such as ergosterol under the effect of ultraviolet rays. The ergosterol is taken in in very small quantities through the yeast which the meharists use sparsematically to cook their griddle-cakes.

3. Vitamin PP, the Pellagra-Combatant Vitamin

A very deficient intake: 4 milligrams instead of the 15 to 25 milligrams per day required. Whence the frequency of pre-pallagral states characterized by ulcerous gingivo-stomatitis with glossitis, pyrosis and difficulties in the intestinal tract. The "black tongue" which first indicates this hypovitaminosis finds its minor equivalent in the brownish pseudo-addisonian spots covering the lingual, labial, jugal and pharyngeal mucosa.

4. Vitamin B

Thiamine, Vitamin B1, an antineuritic, has a sufficient intake of 2.5 mg/day thanks to the flour, pastes and couscous, and to a lesser degree the sardines and oil, tomato concentrate and onions.

Vitamin B2 or riboflavin, on the contrary, is deficient: 0.13 mg/day /49
instead of the 2.2 to 3.3 mg required. Angulus infectiosus, glossitis and symptoms of a ariboflavinosis are frequently associated with the pre-pallagral ailments observed in Saharans. It is in this perspective that we have systematically treated these ailments through the association of Vitamin B2 and Vitamin PP with satisfactory results.

5. Vitamin C, Ascorbic Acid

Instead of the 70 to 100 milligrams required daily, the diet offers only 18 milligrams, resulting in chronic hypovitaminosis, as witnessed by the terrible condition of the meharist's mouth: gingivo-stomatitis, pyorrhea, extensive gingival agomphiasis. This is not a question of true scorbutus, but rather pre-scorbutic states which regress rapidly after administration of Vitamin C.

In concluding this first analytical part, we will note the major insufficiencies and imbalances between the various nutriments which characterize the eating habits of the populations indigenous to the desert zone. A more detailed study of the alimentary efficiency, and the vitamin rations will confirm the data. Therefore, we will be in a position to question how the organism reacts and adapts itself to a rather low energy intake. We will attempt to find an explanation for this through a discussion of the concept of maintaining caloric-nitrogen levels, prior to studying the effects of these eating habits on the thermal-energy controls.

Adaptation of the Caloric-Nitrogen Maintenance Level

We have seen that the minimum nitrogen requirement is a function of the alimentary regimen and the biological value of the nutriments. However, the organism has the faculty of being able to adapt its energy requirement within a very extended range of protein nitrogen amounts. It is quite difficult to give evidence of the organism's failing as a result of total protein starvation, because highly precise experiments taken in man as well as in animals show that the organism is capable of satisfying its energy needs in the face of a very low and variable protein intake from 0.2 g to 3-4 g of nitrogen per kilogram of body weight. For a man weighing 60 kilograms, this represents nitrogen values varying from 12 grams to 240 grams per day. As has been stated by Tremolieres, "nitrogen distribution is almost always balanced if we wait long enough. It is possible to balance the N distribution for almost any N intake, in other words, the nitrogen outlay of protein starvation is not the minimum outlay, which seems quite capable of being two or three times lower."

The works by Guillemet and Mandel in dogs and Keys in man confirm these data.

Here we have examples which give us an idea of how the Saharan balances his distribution from a deficient nitrogen intake. The organism submitted to partial and prolonged protein starvation balances its requirements in accordance with a low level for calories and nitrogen, thanks to adaptative /50 metabolic processes which behave in manners which are still poorly understood. Thus, the nitrogen requirement is not a static concept but, on the contrary, a dynamic state which is modified with respect to the nutritional state. The overfed European balances his distribution at a high level based on a substantial intake of exogenic nitrogen. The Saharan, submitted to constant protein starvation, balances his own distribution on a much lower level, but the organic requirements are safeguarded through very delicate metabolic adjustments. Tremolieres adds that "experiments have shown that any modification of ingestion modifies the excreta only through its effects on the organism. We are dealing with a system composed of three factors which adjust themselves reciprocally:

AMOUNT INGESTED → AMOUNT EXCRETED

NUTRITIONAL STATE

The vague mechanism of ancestral adaptation to a hostile environment is at the base of any attempted explanation with respect to these very unique eating habits. As has been stated by Pedoya, "Secular adapation and ethnic characteristics certainly have a bearing: The water and electrolyte economy of the Touareg and the Reggibat is doubtless different from that of the European who must spend time in the Sahara."

Nevertheless, we must certainly acknowledge that a substantial part of the selection of diet reverts to obscurantism and ignorance of norms of nutritional hygiene, without forgetting the factors of custom and the fact that if the Saharan nomad eats so little and so poorly, it is because his choice is, in spite of everything, rather restricted.

II. Eating Habits and Thermo-Energy Controls

This adaptation, as we have said, seems to be due to adjustments of the organic requirements through which, for example, vegetable proteins are used to their maximum yields, counteracting a meat deficiency. In the Saharan nomad, these caloric and energy requirements are largely satisfied with a totally unbalanced intake. In this we see justification for Bayliss's aphorism: "Take care of your calories and the proteins will take care of themselves." Such a balance would be precarious without the intervention of metabolic interconversion processes.

In fact, in order for glucides and fats to be able to compensate for the deficiency in animal protein, we must assume the existence of interrelationships which go through the large metabolic areas, the tricarboxylic cycle of Krebs, the dicarboxylic cycle of Thunberg-Wieland, etc. Through the technique of tagged atoms, Rittenberg and Stetten have revealed the importance of these metabolic interconversions which permits economizing of protein reserves. The recent works by Allison and Swanson have shown the important action of protein reserve which glucides and lipids may have. In addition, French, Cowan and Swift have brought to light "the dynamic effect of foods" (a concept differing from Rubner's isodynamic law), i.e. rendering comparable in equal /51
quantities, proteins, lipids and glucides in metabolic exchanges. These authors have proved that a substantial proportion of lipids in the diet "compared with other diets with equal energy values, leads to a decrease in the caloric production and a better energy yield" (Cahn). Is this not justification for the paradoxical remark made by the old Saharan that would affirm to us that fats aid in combatting heat?

What happens to thermoregulation in such a torrid climate but with a very substantial caloric diet?

First let us briefly recall the concepts of thermal zero and energy zero, which we will make use of.

The study of energy balances in normal subjects shows that basic consumption, i.e. the minimum energy used by the subject at complete rest, is at its lowest point when the man has an outside temperature of 33° (Rubner and Lefebvre), a temperature 4° below that of the body's internal temperature of 37°, the latter defining the thermal zero. At this level, 37° outside temperature, the organism is in balance with the external environment and there is no exchange taking place between the organism and its environment. However, internal exothermic combustion yields a surplus of calories which the organism must eliminate if it wishes to maintain its euthermia (Giaja).

There is an energy level at which this extra heat, instead of being eliminated by the organism, will be used to heat and maintain the euthermia level of 37°. This energy level is 33° for a naked man at rest.

At this level, the level for the internal combustion serves exactly to fill the deficiency of 4° between the energy zero and the thermal zero. It is in this way that we define the energy zero level for which the organism insures his thermal regulation with a minimum of expense through using its own energy without any additional intake. This liberated extra heat comes from nutrition, among other ways from the specific dynamic action (S.D.A.), an idea which has been known and defined since the works of Rubner (1902). At temperatures below the 37° thermal zero level, "this hyperproduction is not observed because the extra heat which is produced is used for thermogenesis and reheating" (Kayser).

Let us apply these data to the meharists...

For the most part of the year, he lives in an environment whose temperature ceiling is above 37°, i.e. temperatures substantially surpassing his thermal zero level. In this case, the caloric requirements for the organism are satisfied and homeothermia is safeguarded through exacerbated thermolysis. The extra heat due to the S.D.A., the surplus calorie yield above the thermal balance, is radiated as a pure loss.

When we have the mean value for the S.D.A. of the nutriments (proteins: 30%, glucides: 13% and lipids: 6%), it is easy to calculate the extra heat in the case of the Saharan's diet

TABLE IV /52

	Proteins	Lipids	Glucides
Daily gram intake	111	653	105
Daily caloric intake	372	2594	976.5
S.D.A. in calories/day	111.6	337	58.5
Total S.D.A.		512 calories/day.	

Thus, the S.D.A. for the food yields an intake averaging 512 calories per day and an energy intake "which can be used only in the form of heat... This is a true loss which escapes the control that guarantees constant 24 hour production" (Cahn).

In the winter, the outside temperature varies between 0° and 25°, clearly below the thermal nutrality. In this case, the extra heat from the S.D.A. is enclosed within the thermogenesis and completes the physical and chemical thermoregulatory mechanisms.

Thus, the Saharan's diet, inadequate from the qualitative viewpoint, presents the same imbalance from the viewpoint of thermal regulation to heat.

However, this inadaptation to thermoregulatory requirements is not of primary importance aside from the fact that it is the basis for a certain discomfort during the Saharan summer.

The adaptation to the energy requirements demanded by physical exercise is pre-eminent and should be considered primarily if we wish to correct these alimentary deviations. In fact, Kark in particular has shown that the energy requirement depends less on the exterior temperature than on the mechanical energy used. Thus, energy balances during exercise at high and low temperatures show that the increase in the metabolism is proportionately less important than the energy increase imposed by the heavy clothing being carried. The following table, taken from Pedoya, substantiates this fact.

TABLE V

Climate	Basal Metabolism	Work
Heat. . . .	1700 calories	+1400 calories (130 of which to carry clothing).
Cold. . . .	2100 calories	+2800 calories (1400 of which to carry clothing).

Conclusion /53

The study of this particular case which represents alimentation of the Saharan nomad has permitted us to examine the organic behavior of man in an exceptional environment, the torrid desert climate.

These eating habits show lacks and aberrations which are both quantitative and qualitative, and which are due to many factors: economy, practice, custom, etc.

This deficient diet represents inadaptation of eating habits to the heat and energy requirements imposed upon the organism by the nomadic life and the climate, which especially favors the thermolytic process.

Faced with this distorted alimentary process, the organ in order to compensate for this deficiency, is forced to adapt its requirements along a particularly low calorie and nitrogen level thanks to which a metabolic equilibrium is maintained. This acclimation is achieved through adjustments of the organic requirements to the alimentary exogenous intake, to a hydro-electrolytic metabolism adapted to intense thermolysis, a process safeguarding homeostasis.

There remain many vague aspects in this study of acclimation. If although these water and electrolyte changes have been partially clarified, the nutritional adjustments, particularly adaptation to a particularly low level of calorie and nitrogen maintenance, remain related to unknown mechanisms.

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